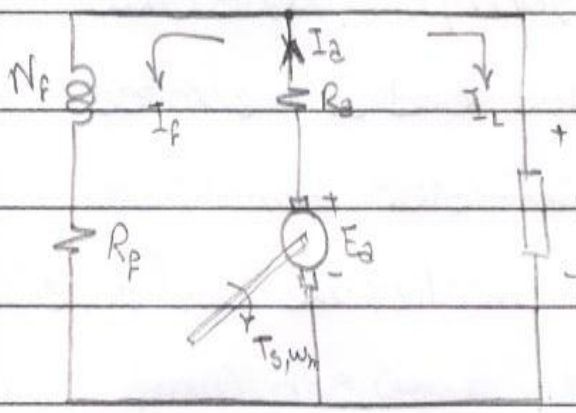
Direct Current Generator

[i] Shunt Generator



equivalent ct. of shunt Gen.

$$P_{out} = V_t I_L \quad \text{(watt)}$$

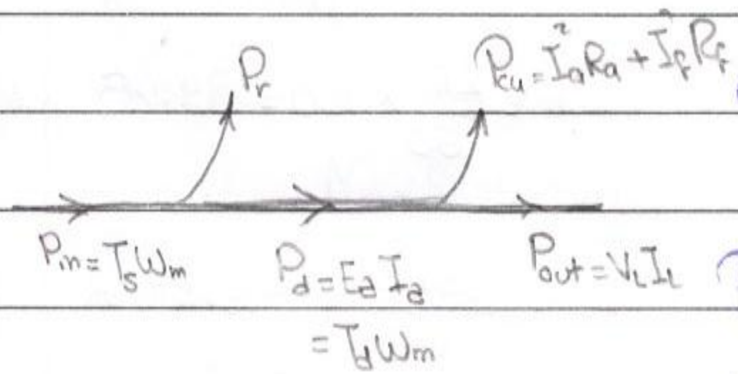
$$P_{in} = T_{sh}\,\omega_m \quad \text{(watt)}$$

$$\omega_m = \frac{2\pi}{60} N_m \quad \text{(rad/sec)}$$

$$I_a = I_f + I_L \quad \text{(Amp)}$$

$$I_f = \frac{V_t}{R_f} \qquad I_L = \frac{P_{out}}{V_t}$$

$$E_a = K_a \phi_p \omega_m = V_t + I_a R_a$$



$$P_d = E_a I_a = T_d \omega_m$$

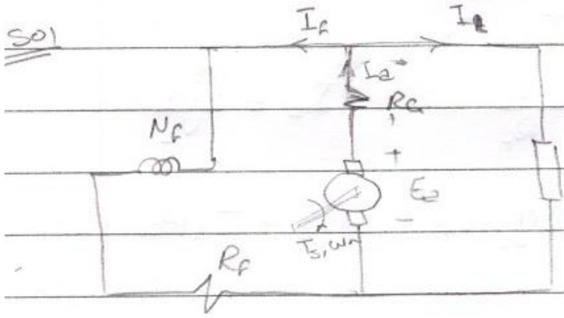
$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Example : (3-11) P. (3-40)

A 50-KW, 120 V shun generator has $R_a = 0.09\Omega$, $R_{fw} = 30\ \Omega$, $R_{fx} = 15\Omega$, $N_m = 900\ rpm$, $P_r = 5KW$. The generator is delivering the rated load at the rated terminal voltage. Det. a) the generator emf

T_{sh} b) torque applied (c) efficiency. Neglect the armature reaction.

Sol

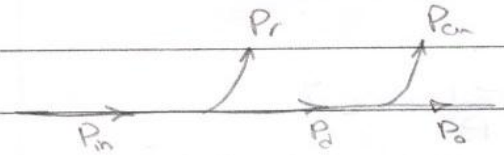


$R_f = R_{fx} + R_{fw}$

$= 30 + 15 = 45\Omega$

$\omega_m = \frac{2\pi}{60} * 900 = 94.25\ rad/s$

$I_L = \frac{50 \times 10^3}{120} = 416.67\ A$



$I_f = \frac{V_L}{R_f} = \frac{120}{45} = 2.67A$

$\therefore I_a = I_f + I_L = 416.7 + 2.67 = 419.367\ A$

(a) $E_a = V_L + I_a R_a = 120 + (419.367 * 0.09) = 157.743\ V$

(b) $T_{sh} = \frac{P_{in}}{\omega_m}$

$P_{in} = P_r + P_d = P_r + E_a I_a = 5 \times 10^3 + (157.743)(419.367)$
$= 71.152 \times 10^3\ watt$

$\therefore T_{sh} = \frac{71.152 \times 10^3}{94.25} = 754.93\ N.m$

(c) $\eta = \frac{P_o}{P_{in}} \times 100 = \frac{50 \times 10^3}{71.152 \times 10^3} \times 100 = 70.27\ \% \sim 70\%$

A DC shunt generator driven at speed of 900 rpm. The load draw a current of 200 A for a magnetic flux per pole as 0.1 wb. the machine parameters are armature circuit resistance = 0.1 Ω, field circuit resistance = 130 Ω, lap connected armature conductor = 300

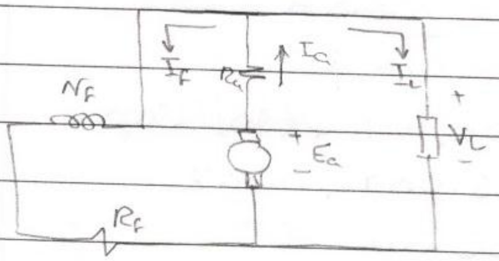
- draw the generator circuit and its power flow diagram
- for an eff. of 80% calculate percentage voltage regulation, field and armature current, rotational and current losses, and the torque applied on the shaft.

Givens:- $N_m = 900$ rpm $\quad I_L = 200A \quad \phi_p = 0.1$ wb

$R_a = 0.1\,\Omega \quad R_f = 130\,\Omega \quad$ Lap conect. $a = p$

$Z = 300$ conductor

Sol:-



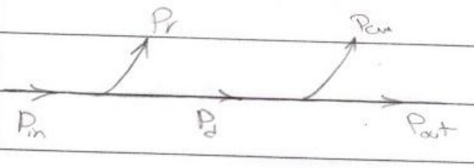
$\therefore \omega_m = \frac{2\pi}{60}(900) = 94.25$ rad/sec

$E_a = K_a \phi_p \omega_m$

$K_a = \frac{PZ}{2\pi a} = \frac{300}{2\pi} = 47.75$

$\therefore E_a = (47.75)(0.1)(94.25)$

$= 450$ V



$\therefore E_a = V_L + I_a R_a$

$= V_L + (I_L + I_F) R_a$

$450 = V_L + (I_L + \frac{V_L}{R_F}) R_a$

$450 = V_L + (200)(0.1) + (\frac{0.1}{130}) V_L$

$450 = V_L + 20 + (\frac{0.1}{130}) V_L$

$430 = 1.000769\, V_L$

$V_L = 429.66$ V

$\therefore P_{out} = V_L I_L = 429.66 * 200$

$= 85.93$ kw

$\eta = 80\% = \frac{P_o}{P_{in}} \times 100$

$\frac{85.93 \times 10^3}{P_{in}} = 0.8$

$P_{in} = 107.417$ kw

* $P_d = E_a I_a = 450 \times (I_f + I_L) = 450\left(\frac{V_L}{R_f} + 200\right)$

$$= 450\left[\frac{429.99}{130} + 200\right]$$

$$= 91.488 \text{ KW}$$

* $\therefore P_r = P_{in} - P_d$

$$= 107.417 - 91.488 = 15.925 \text{ KW}$$

* $V.R = \frac{E_a - V_t}{V_t} \times 100 = \frac{450 - 429.99}{429.99} * 100$

$$= 4.653$$

* $I_f = V_L / R_f = 429.99/130 = 3.3 \text{ A}$

$I_a = I_f + I_L = 3.3 + 200 = 203.3 \text{ A}$

* $P_{cu} = I_a^2 R_a + I_f^2 R_f = (203.3)^2(0.1) + (3.3)^2(130)$

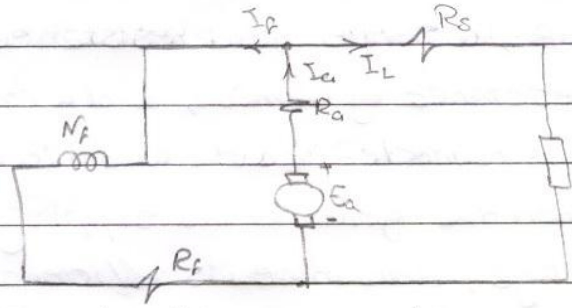
$$= 4133.089 + 1422.2$$

$$= 5.55 \text{ KW}$$

* $T_{sh} = \frac{P_{in}}{\omega_m} = \frac{107.417 \times 10^3}{94.25} = 1139.7 \text{ N.m}$

* Compound Generator :-

- Short shunt

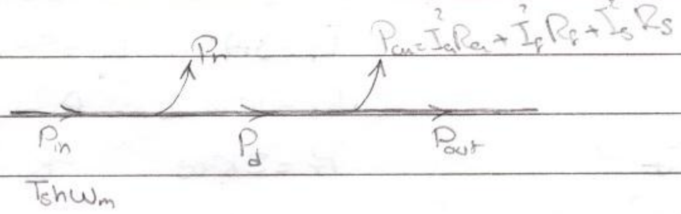


"equivalent ct. of short-shunt"

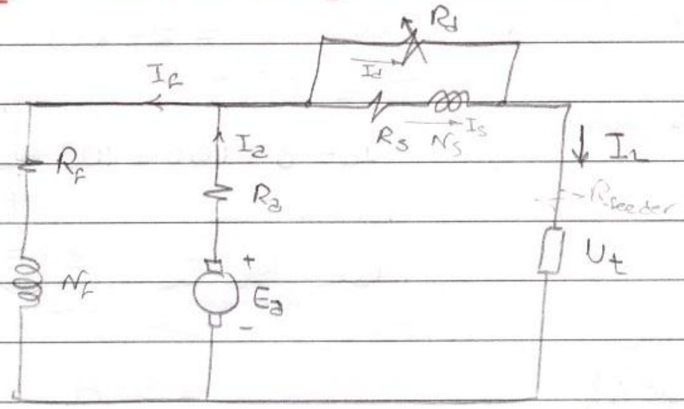
$$I_a = I_L + I_f$$

$$I_s = I_L$$

$$V_t = E_a - I_a R_a - I_L R_s$$



OR "another design"



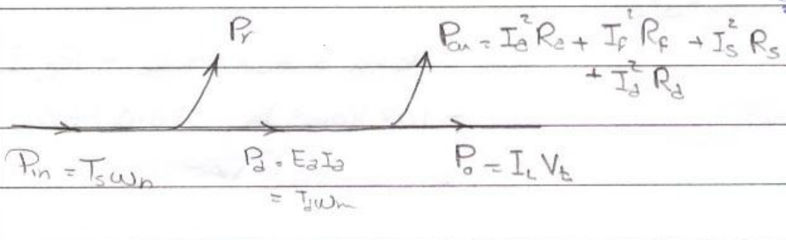
$$E_a = I_a R_a + \underbrace{I_s R_s + U_t}_{I_f R_f}$$

or

$$E_a = I_a R_a + I_f R_f$$

$$I_a = I_L + I_f$$

$$\therefore I_L = I_s + I_d$$



• ممكن يجي يقول انه ربط ct. series بال V_t يعني ال feeder

$$\therefore E_a = R_a I_a + R_s I_s + I_L R_{feeder} + U_t$$

$$P_{cu} = I_L^2 R_{feed} + I_a^2 R_a + I_f^2 R_f + I_s^2 R_s + I_d^2 R_d$$

Example:-

A 240V, short-shunt, cumulative compound generator is rated at 100A, the shunt field current is 3A. It has an armature resistance of 50 mA, a series field resistance of 10mΩ, a field diverter resistance of 40mΩ, and a rotational loss of 2KW, the generator is connected to the load via a feeder R_{fe} of 30mΩ resistance, when the generator is supplying the full load at the rated voltage, determine its efficiency. Draw the power flow diagram to show the power distribution.

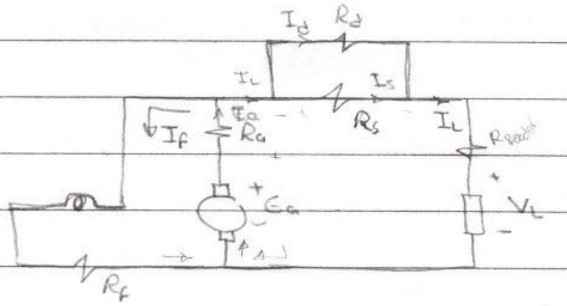
Given $V_L = 240V$ $I_L = 100A$

$I_f = 3A$ $R_a = 50m\Omega$

$R_s = 10m\Omega$ $R_d = 40m\Omega$

$P_r = 2KW$ $R_s = 10mA$

$R_{fe} = 30m\Omega$



$$P_o = I_L V_L = 240 * 100$$
$$= 24\ KW$$

$$I_a = I_f + I_L$$
$$I_a = 3 + 100 = 103\ A$$

Current divider

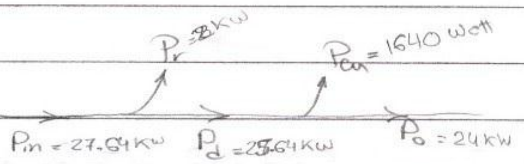
$$I_s = \frac{R_d}{R_d + R_s} I_L = \frac{0.04}{0.04 + 0.01} * 100$$
$$= 80\ A$$

$$\therefore I_d = I_L - I_s = 100 - 80 = 20\ A$$

$$E_a = I_a R_a + I_s R_s + V_L + R_{fe} I_L$$
$$= (103)(0.05) + (80)(0.01) + 240 + (0.03)(100)$$
$$= 248.95\ V$$

$$P_d = E_a I_a = 248.95 * 103 =$$
$$= 25.64\ KV$$

$$\therefore P_{in} = P_d + P_r = 25.64 * 10^3 + 2 * 10^3$$
$$= 27.64 * 10^3\ watt$$



$$\therefore \eta = \frac{P_o}{P_{in}} * 100$$

$$= \frac{24 \times 10^3}{27.64 * 10^3} * 100 = 93.58\%$$

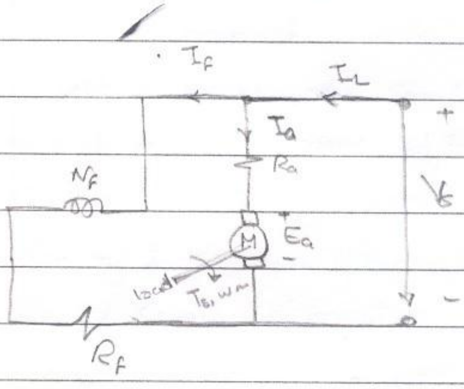
$$P_{cu} = I_a^2 R_a + I_f^2 R_f + I_s^2 R_s + I_d^2 R_d + I_{fe}^2 I_{fe} =$$

watt

- if given N

$$\therefore T_s = \frac{P_{in}}{\omega_n}$$

Direct current Motor.



"equ. ct. of shunt motor"

Eqs back emf

$I_L = I_f + I_a$

$P_{in} = V_s I_L$

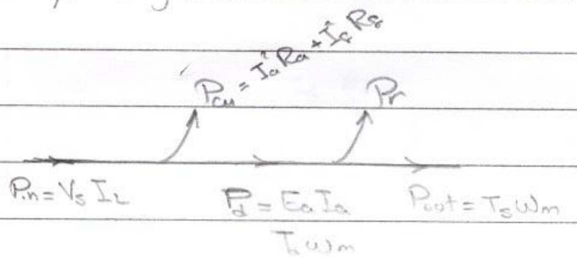
$P_{out} = T_s \omega_m$

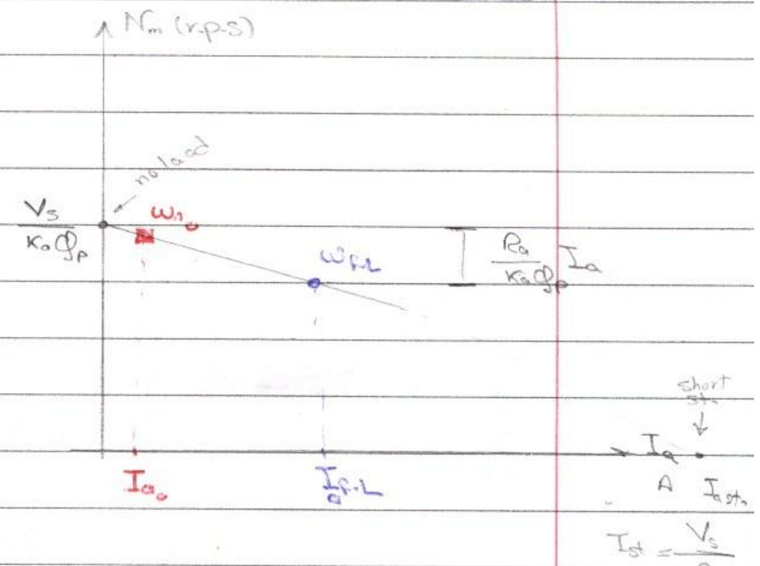
$V_s = I_f R_f$

$E_a = V_s - I_a R_a$

$E_a = K_a \Phi_p \omega_m$

$$\therefore \omega_m = \frac{V_s}{K_a \Phi_p} - \frac{R_a}{K_a \Phi_p} I_a$$





$$V_R = \frac{V_{no\,Load} - V_{F.L}}{V_{F.L}} \times 100$$

speed regulation

$$= \frac{N_{n.L} - N_{F.L}}{N_{F.L}} * 100$$

Sketch speed current clc's.

Power flow diag. ق رسمتين لل

1- at no load $\Rightarrow P_{out} = 0$

ساعتها أقدر أجيب الـ P_r

2- at full load $\Rightarrow$ الرسم العادي

$\therefore$ No-load speed

$$\omega_{nL} = \frac{V_s}{K_a \Phi_p}$$

ولازم أوضح للأرقام على الرسمة

سواء power flow diag. أو

الـ speed current clc's

$\therefore$ Speed drop

$$\Delta \omega = \frac{R_a}{K_a \Phi_p} I_a$$

Keep

$$\frac{E_a|_{n.L}}{E_a|_{F.L}} = \frac{N_m|_{n.L}}{N_m|_{F.L}}$$ at const $K_a \Phi_p$

$I_{st} = \frac{V_s}{R_a}$ "starting current"

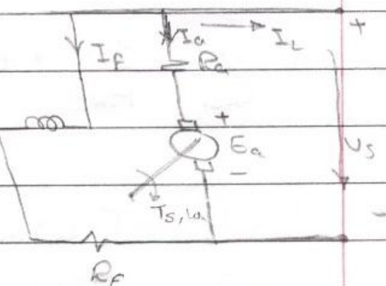
Example (4.2) A 240 V shunt motor takes a current of 3.5 A on no load. the armature ct. resistance is 0.5 Ω and the shunt-field-winding resistance is 160 Ω. When the motor operates at full load at 2400 rpm, it takes 24 A. Determine (a) η_{FL} (b) torque developed and useful torque (T_d & T_s) (c) no-load speed (d) percent speed regulation. sketch power-flow diagram for each operating condition.

Given:- $V_s = 240\,V$ $\quad I_{L_{n.L}} = 3.5\,A$ $\quad R_a = 0.5\,\Omega$

$R_f = 160\,\Omega$ $\quad \omega_{FL} = 2400$ rpm. $\quad I_{L_{FL}} = 24\,A$

Sol:-

At No load

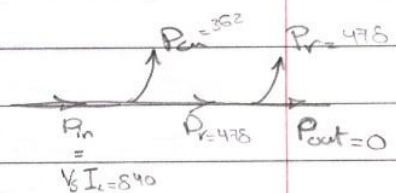


$\therefore I_{f_{N.L}} = V_s/R_f = 240/160 = 1.5\,A$

$\therefore I_a = I_L - I_f = 3.5 - 1.5 = 2\,A$

$E_a = V_T - I_a R_a$

$= 240 - (2)(0.5) = 239\,V$



$\therefore P_d = E_a I_a = (239)(2) = 478$ watt

$\therefore \boxed{P_r = P_d = 478 \text{ watt}}$ *

$P_{cu} = I_a^2 R_a + I_f^2 R_f = (2)^2(0.5) + (1.5)^2(160)$

$= 2 + 360 = 362$ watt

$\therefore P_{in} = P_{cu} + P_d = 362 + 478 = 840$ watt

$P_d = T_d \omega_m$

at full load

$I_f = 240/160 = 1.5$

$I_{a_{FL}} = I_{L_{FL}} - I_f = 24 - 1.5 = 22.5\,A$

$E_a = V_T - R_a I_a = 240 - (0.5)(22.5) = 228.75\,V$

$P_d = E_a I_a = (228.75)(22.5) = 5.147\ kW$

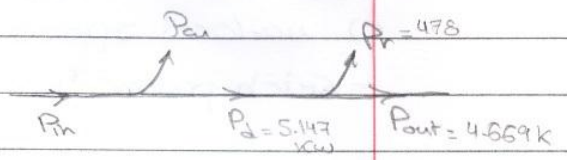
$\therefore P_{out} = P_d - P_r = 5.147\times10^3 - 478 = 4.669\ kW$

$P_{cu} = I_{a_{F.L}}^2 R_a + I_f^2 R_f$

$= (22.5)^2(0.5) + (1.5)^2(160)$

$= 613.125\ watt$

$= P_{in} - P_d$



$P_{in} = V_s I_L = (240)(24) = 5.76\ kW$

(a) * $\therefore \eta_{F.L.} = \dfrac{P_{out}}{P_{in}} * 100 = \dfrac{4.669}{5.76} * 100 = 81.06\%$

(b) * $P_d = T_d \omega_m$

$T_d = \dfrac{5.147\times10^3}{\frac{2\pi}{60}(2400)} = 20.48\ N.m$

$T_{sh} = \dfrac{P_{out}}{\omega_m} = \dfrac{4.669\times10^3}{\frac{2\pi}{60}(2400)} = 18.57\ N.m$

(c) $N_{n.L} = 2400 * \dfrac{E_{a\,n.L}}{E_{a\,F.L}} = 2400 * \dfrac{239}{228.75}$

$= 2507.54\ (r.p.m)$

(d) speed regulation $= \dfrac{N_{n.L} - N_{F.L}}{N_{F.L}} * 100 = \dfrac{2507 - 2400}{2400} * 100$

$= 4.48\%$

أتى في كويز جديد
جزئ بالامتحان

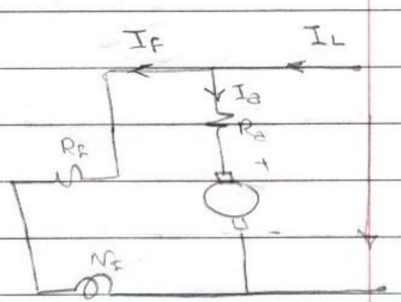
Exercise:

(4.5) A 120V shunt motor takes 4A when it operates at ~~speed~~ its no-load speed of 1200 rpm. Its armature winding resistance is 0.8 Ω and the shunt field resistance is 60 Ω. Determine the efficiency and the speed of the motor when it delivers its rated load of 2.4 kW. P_o

Givens:-

$V_s = 120V$ $\qquad I_{L_{n.L}} = 4A$ $\qquad N_{n.L} = 1200 rpm$

$R_a = 0.8\,\Omega$ $\qquad R_s = 60\,\Omega$



→ at no. Load

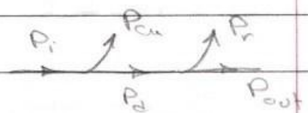
$P_{out} = 0$

$\therefore P_d = P_r$

$P_d = E_{a n.L} * I_{a n.L}$

$E_a = V_s - I_a R_a$

$I_a = I_L - I_f$



$\therefore E_a = V_s - \left[I_L - \frac{120}{60} \right] 0.8$

$= 120 - (4-2) \times 0.8 = 118.4\ V$

$\frac{E_{a\,n.L}}{E_{a\,f.L}} = \frac{N_{m\,n.L}}{N_{m\,f.L}}$

$N_{m\,fL} = \frac{99 \times 1200}{118.4}$

$= 1003.37$

$\therefore P_d = P_r = 118.4 \times 2 = 236.8\,W$

→ A full load

$E_{a_{f.L}} = V_s - I_{a_{f.L}} R_a$ مش عارفين نحسب ولا

عشان كدا هنعوض ب I

$P_d = I_a E_a = I_a V_s - I_a^2 R_a$

$P_d|_{f.L} = 120\, I_{a_{f.L}} - 0.8\, I_{a_{fL}}^2$

$P_{d\,fL} = P_r + P_{out} = 236.8 + 2.4 \times 10^3 = 2636.8$

& $2636.8 - 120\, I_{a\,fL} + 0.8\, I_{a\,fL}^2 = 0$

$I_a = 123.25$ $\qquad I_a = 26.7$ $\qquad$ باخد القيمة الأصغر

refused

$\therefore E_a = \frac{P_d|_{f.L}}{I_a|_{f.L}} = 98.7 \simeq 99\,V$

$\therefore I_L = I_a + I_f = 26.7 + 2 = 28.75\,A$

$P_{in} = V_s I_L = (120)(28.75) = 3450\,watt$

$\eta = \frac{P_{out}}{}\times 100 = 69.56\,\%$

Exercise (4.6)

A 220V - shunt motor draws 10A at 1800 rpm. The armature-circuit resistance is 0.2 Ω, and the field-winding resistance is 440 Ω. The rotational loss is 180 w. Determine

(a) back emf (b) driving torque (c) shaft torque

(d) efficiency of the motor.

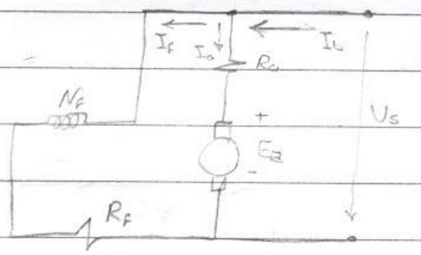
sol:-

Given:-

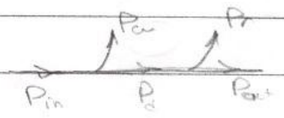
$V_s = 220V \quad I_L = 10A \quad N = 1800$

$R_a = 0.2\Omega \quad R_f = 440\Omega$

$P_r = 180$



$\therefore I_f = V_s/R_f = \frac{220}{440} = 0.5A$



$I_a = I_L - I_f = 10 - 0.5 = 9.5\ A$

(a) $E_a = V_T - I_a R_a = 220 - (9.5)(0.2) = 218.1\ V$

(b) $P_d = E_a I_a = (218.1)(9.5) = 2.07195\ kw$

$$T_d = \frac{P_d}{\omega} = \frac{2.07195\times10^3}{\frac{2\pi}{60}(1800)} = 10.992\ N.m$$

$P_{in} = V_s I_L = (220)(10) = 2200\ watt$

$P_{out} = P_d - P_r = 2.07195\times10^3 - 180$

$= 1.89195\ kw$

(c) $\therefore T_{sh} = \frac{P_{out}}{\omega} = \frac{1.89195\times10^3}{\frac{2\pi}{60}(1800)} = 10.037\ N.m$

(d) $\eta = \frac{P_o}{P_{in}} \times 100 = \frac{1.89195K}{2200} = 85.99\ \%$

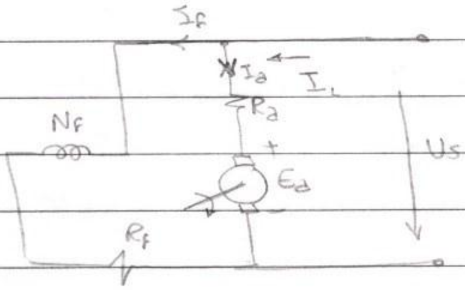
A dc shunt motor drive a load for a supply voltage of 220 V. the armature current is measured as 25 A. and the rated speed is accounted to be 2200 rpm. The machine resistances are 0.8 ohm for the armature and 120 ohm for the field winding

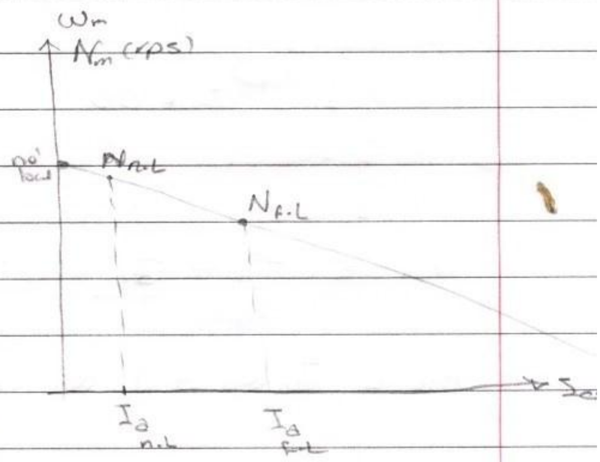
- draw the motor circuit and its power flow diagram
- calculate the machine const. $K_a\phi_p$, the no load speed N_{nL} the torque on the shaft for a rotational losses of 100 W
- and motor efficiency.
- sketch without any scale the speed current characteristics showing the rated and no load value.

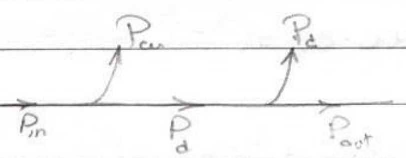
مادام اداك الـ I يبقى F.L

Given:- $V_s = 240\,V$ $\quad I_a = 25\,A$ $\quad N = 2200\ rpm$

$R_a = 0.8\,\Omega$ $\quad R_f = 120\,\Omega$







$$E_a = K_a\phi_p \omega_m = V_T - I_a R_a$$

$$K_a\phi_p = \frac{240 - (25)(0.8)}{\frac{2\pi}{60} \times 2200} = 0.955\ (V/rad/sec)$$

$$K_a\phi_p = 0.955\ (V/rad/sec)$$

$$\therefore \omega_m = \frac{V_s}{K_a\phi_p} - \frac{R_a}{K_a\phi_p} I_a$$

at no load $\quad \omega_m = \frac{V_s}{K_a\phi_p} = \frac{240}{0.955} = 251.327\ rad/sec$

لما يقول rated speed ⇐ $N_{f.L}$ او اي rated نبقى F.L

$$N_{m_{n.L}} = 60 * 251.3/2\pi = 2400 \text{ rpm}$$

At full load

$$P_d = E_a I_a$$

$$\because E_a = V_t - I_a R_a = 240 - (25)(0.8) = 220V$$

$$P_d = 220 * 25 = 5.5 \text{ KW}$$

$$P_{out} = P_d - P_r = 5.5K - 100$$
$$= 5.4 \text{ KW}$$

$$T_{sh} = \frac{P_{out}}{\omega} = \frac{5.4\times10^3}{\frac{2\pi}{60}(2200)} = 23.439 \text{ N.m}$$

$$\eta = \frac{P_{out}}{P_{in}} * 100$$

$$P_{in} = P_{cu} + P_d$$

$$P_{cu} = I_a^2 R_a + I_f^2 R_f = (25)^2(0.8) + \left(\frac{V_L}{120}\right)^2 120$$

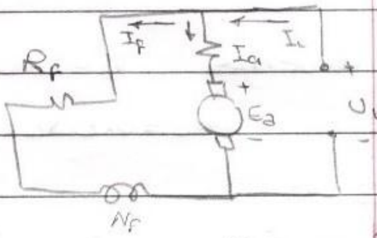
$$= 500 + 480 = 980 \text{ W}$$

$$\therefore P_{in} = P_d + P_{cu} = 5.5\times10^3 + 980$$
$$= 6.48 \text{ KW}$$

$$\eta = \frac{5.5}{6.48} * 100 = 84.87 \%$$

Exercise (4.7)

A 220V shunt motor draws 10 A at 1800 rpm. The armature-circuit resistance is 0.2 Ω and the field winding resistance is 440 Ω. The rotational loss is 180 w. If the torque developed by the motor is 20 N.m. Determines- a) speed (N) (b) line current (I_L) (c) effeciency.

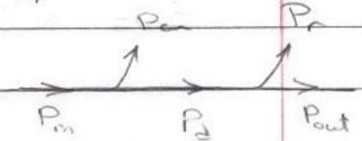


Givens $V_t = 220V$, $I_L = 10A$

$N = 1800$ rpm $R_a = 0.2\ \Omega$

$R_f = 440\ \Omega$ $P_r = 180\ w$

$T_d = 20$ N.m



Sol/

يجيب الـ T_s في حالة الـ full load and Power — ويجيب الـ Speed at no.load.

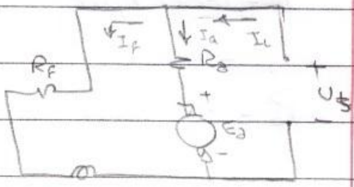
Examples:-

DC-shunt motor drive a load for supply voltage 240V. The armature current = 25 A. The rated speed = 2200 rpm $R_a = 0.8\,\Omega$ $R_f = 120\,\Omega$

calculate:-
1- Machine const. $(K_a \phi_p)$
2- $N_m|_{n.L}$
3- $T_s \rightarrow P_r = 100\,W$.

Given:- $V_t = 240V$ $I_a = 25A$ $N_{F.L} = 2200$ rpm
$R_a = 0.8\,\Omega$ $R_f = 120\,\Omega$

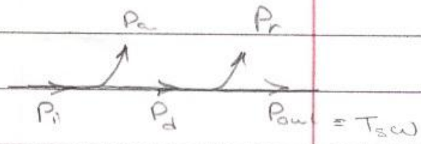
sol:-



$$E_a = K_a \phi_p \, \omega_m$$

$$E_a = U_s - I_a R_a = 240 - (25 \times 0.8) = 220V$$

$$\therefore K_a \phi_p = \frac{E_a}{\omega_m} = \frac{220}{\frac{2\pi}{60}(2200)} = 0.9549 \; V/(rad/sec)$$



$$\therefore P_{out} = P_d - P_r = (220)(25) - 100 = 400 \text{ watt}$$

$$\therefore T_{sh} = \frac{P_{out}}{\omega_{f.L}} = \frac{400}{\frac{2\pi}{60}(2200)} = 1.736 \; N.m$$

→ At No-load.

$$P_o = 0$$

$$\therefore P_r = P_d = E_{a_{n.L}} I_{a_{n.L}}$$

$$E_{a_{n.L}} = V_s - I_{a_{n.L}} R_a$$

$$P_{d_{n.L}} = I_{a_{n.L}}(240) - I^2_{a_{n.L}}(0.8)$$

$$100 = 240\, I_{a_{n.L}} + 0.8\, I^2_{a_{n.L}}$$

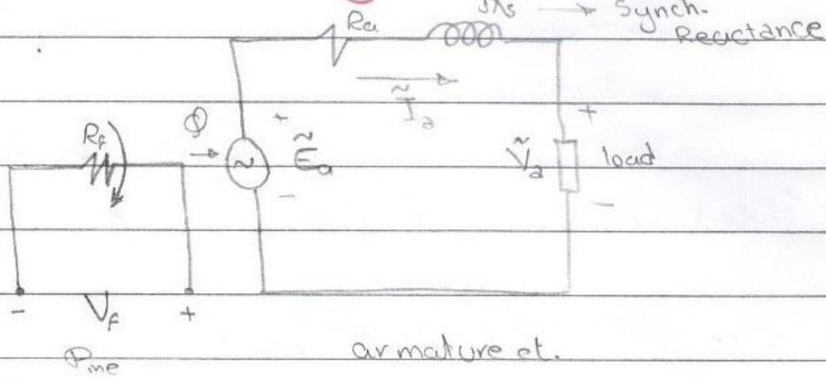
$I_a = 299.58$ refused $I_{n.L} = 0.417$

$$\therefore E_{a_{n.L}} = 240 - (0.417)(0.8) = 239.66V$$

$$\therefore \frac{E_{a_{f.L}}}{E_{a_{n.L}}} = \frac{N_{f.L}}{N_{n.L}}$$

$$\therefore N_{n.L} = \frac{(239.66)(2200)}{220} = 2396.66$$

Synchronous Generator.

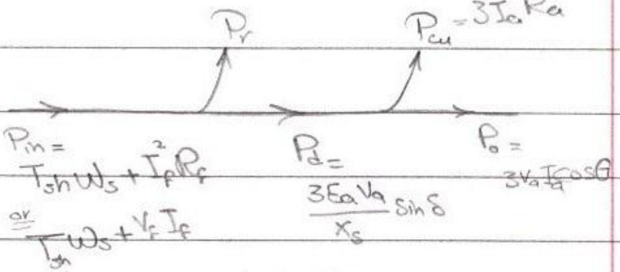


jX_s : synchronous reactance

R_a : synchronous resistance

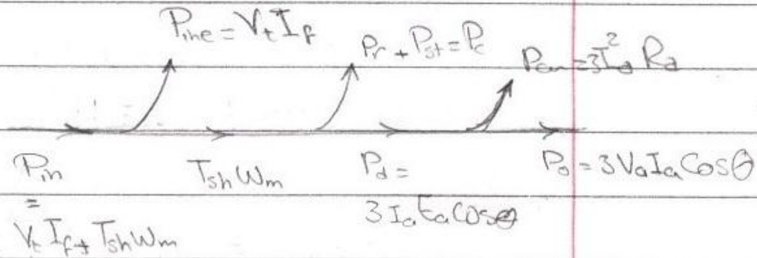
$$\tilde{E}_a = \tilde{V}_a + \tilde{I}_a(R_a + JX_s)$$

$$\omega_s = \frac{2\pi}{60} N_s$$



$$N_s = \frac{120f}{P}$$

$$P_{in} = \omega_s T_{sh} + I_f R_f$$



$$P_d = \frac{3V_a E_a}{X_s} \sin\delta$$

$$V.R\% = \frac{E_a - V_a}{V_a} \times 100$$

$$\eta = \frac{3V_a I_a \cos\theta}{3V_a I_a \cos\theta + P_c + 3I_a^2 R_a}$$

$V_{ph} = \frac{V_{Line}}{\sqrt{3}}$

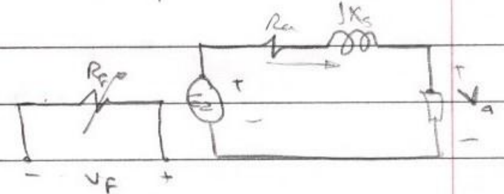
V.V.I Example:-(2.6):-

A 9-KVA, 208-V, threephase, Y-connected, synchronous generator has a winding resistance of 0.1 Ω/phase and a Synchronous reactance of 5.6 Ω/phase. Determine its voltage regulation when the power factor of the load is (a) 80% Lagging (b) unity (c) 80% leading.

Given:- $S = P = 9K$ $V_a = 208V$ Y connection

$R_a = 0.1\ \Omega/\text{phase}$ $X_s = 5.6\ \Omega/\text{phase}$

Sol:-



∴ $V_{phase} = \frac{208}{\sqrt{3}} = 120\ V.$

$V.R = \frac{E_a - V_t}{V_t}$

مع تغير الـ P.F الـ V_a ثابت
اللي بيتغير هو الـ E_a

$E_a = V_t + I_a(R_a + jX_s)$
$= 120 + I_a(0.1 + j5.6)$

يعني لما يتغير الـ P.F هحسب
الـ E_a عند كل حالة.

$I_a = \frac{S}{3V_a} = \frac{9\times10^3}{3\times120} = 25\ A$

∴ $E_a = 120 + 25(0.1 + j5.6)$
$= 122.5 + j140\ V$

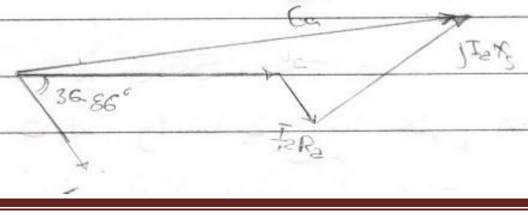
بحط الزاوية مع I_a
في حساب E_a

(a) at 80% lagging

∴ $P.f = 0.8 \Rightarrow \theta = -36.86$ $\cos^{-1} 0.8 = 36.86$

∴ $E_a = 120 + 25\angle{-36.86}\ (0.1 + j5.6)$
$= 120 + (25\angle{36.86})(5.6\angle{88.97})$
$= 120 + 140\angle{52.106^\circ} = 205.988 + j110.48$
$= 233.74\angle{28.206}\ V$

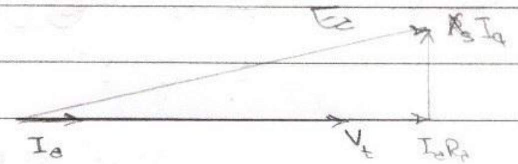
∴ $V.R = \frac{E_a - V_T}{V_t} = \frac{233.74 - 120}{120} * 100$
$= 94.8\%$



(b) unity power factor $\theta = 0^\circ$

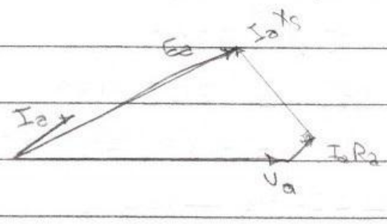
$$\tilde{E}_a = 120 + (0.1 + j5.6)\, 25\angle 0$$
$$= 122.5 + j140 = 186 \angle 48.8^\circ$$

$$\therefore V.R = \frac{E_a - V_T}{V_T} \times 100 = \frac{186 - 120}{120} \times 100 = 55\%$$



(c) 80% leading $= 0.8$ $\theta = +36.86$

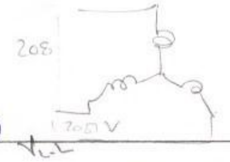
$$\therefore E_a = V_T + 25\angle 36.86\, (0.1 + j5.6)$$
$$= 120 + 25\angle 36.86\, (0.1 + j5.6)$$
$$= 120 + (25\angle 36.86)(5.6\angle 88.976)$$
$$= 120 + 140\angle 125.836$$
$$= 38.034 + j113.49 = 119.693\angle 71.47^\circ \text{ V}$$



$$V.R = \frac{E_a - V_t}{V_t} \times 100 = \frac{119.693 - 120}{120} \times 100$$
$$= -0.2553\%$$

في ال lag & unity لازم V.R تطلع +ve أما ال lead ممكن -ve عادي

E_a: induced emf or exciting voltage.



Given power for 3ph $S = 3\tilde{V}_a \hat{I}_a$

Example (2-7)

A 9-KVA, 208V, 1200 rpm, three phase, 60 HZ, Y connected synchronous generator has a field winding resistance of 4.5Ω. the armature-winding impedance is 0.3+j 5Ω/phase when the generator operates at its full load and 0.8 pf. lagging the field winding current is 5A. the rotational loss is 500W

Determine (a) the voltage regulation.

(b) efficiency of the generator (c) the torque applied by the prime mover.

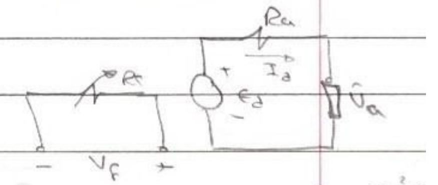
Givens $S = 9\times10^3 = 3V_a I_a$

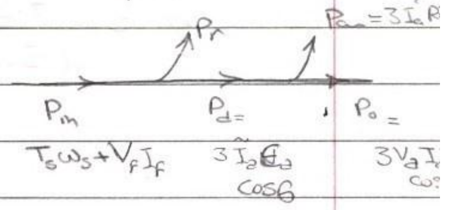
$$V_a = \frac{208}{\sqrt{3}} = 120\ V. \qquad R_a = 0.3\ \Omega \quad X_s = 5\ \Omega$$

$$R_f = 4.5\ \Omega \qquad Pf = 0.8\ lag$$

$$I_f = 5\ A \qquad \theta = -36.86^\circ$$

$$P_r = 500W$$





Sol:-

$$V_a = 120V$$

$$\because S = 3\tilde{V}_a \hat{I}_a$$

$$\therefore I_a = \frac{9\times10^3}{3\times120} = 25\ A$$

$$\therefore I_a = 25 \angle -36.86^\circ\ A$$

$$\because E_a = V_T + I_a(R + jX_s)$$

$$= 120 + 25\angle -36.86^\circ (0.3 + j5)$$

$$= 120 + (25\angle -36.86)(5\angle 86.566)$$

$$E_a = 120 + 125\angle 49.706 = 200.839\angle 95.34^\circ$$

$$\therefore V.R\% = \frac{E_a - V_T}{V_T} = \frac{200.839 - 120}{120} = 67.35\%$$

$$P_o = 3V_a I_a \cos\theta = 3\times120\times25\times0.8 = 7200W$$

$$= S\times0.8 = 7200W = 7.2K$$

$$\eta = \frac{P_o}{P_in}\times100$$

$$P_{in} = T_s\omega_s + V_f I_f$$

$$V_f I_f = 5\underbrace{(5\times4.5)}_{V_f} = 112.5W$$

$$P_d = 3E_a I_a \cos\theta = 3(200.893)(25)(0.8)$$
$$= 7762.4\,W$$

$$\therefore P_{in} = P_r + P_d$$
$$T_s \omega_s = 500 + 7762.4 - 112.5$$
$$= 8149.9$$

$$\therefore T_s = \frac{8149.9}{\frac{2\pi}{60} \times 1200} = 64.85 \text{ N.m}$$

$$\eta = \frac{7.2K}{(500 + 7762.4)} \times 100 = 87\,\%$$

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http://www.com-dep.tk/